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Effect of Cooking Temperature and Time on the Tenderness of Pork

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SUMMARY

The effects on tenderness, cuttability, and shear-press value for pork at specific cooking temperatures over time were determined. The meat was in cylinders to permit rapid heating and chilling. The cooking temperatures investigated were 140, 150, 160, 180, 190, 200, and 210°F.

The initial effect of heat was found to be a toughening that increased as the temperature was increased. There was little change in tenderness with time at 140°F. At 150°F and above, after the initial toughening, the pork became tender to a degree dependent upon both time and temperature. Data scatter indicated that there were considerable differences in the tenderness of individual pieces of pork cooked under the same conditions. Browning and a burnt taste appeared at the higher temperatures.

INTRODUCTION

In small, preliminary procurements of cooked freeze-dried meats for use in new Armed Forces operational rations, lack of tenderness was a major problem. Preliminary investigations at the Armed Forces Food and Container Institute indicated that, of all the variables investigated, cooking cycle had the greatest effect on the tenderness of the final product. In a study concerned with the effect of cooking temperature and time on the tenderness of beef (Tuomy *et al.*, 1963), with internal temperatures below 180°F, time had little or no effect on tenderness. In this case tenderness was found to be a function of temperature and the inherent tenderness of the beef itself. With internal temperatures of 180°F and above, the tenderness attained was a function of temperature, inherent tenderness, and time. The study reported herein was designed to determine the effects of cooking time and temperature on the tenderness of pork. Since preliminary work indicated that properly conducted freeze-drying has almost no effect on the tenderness of freeze-dried meat, the evaluations were conducted on the cooked meat without going through the drying process.

Literature on the tenderness of pork is rather sparse. In the past, most quality studies have been concerned primarily with the carcass and have stressed conformation and fat. The possibility of ingesting *Trichinella spiralis* in contaminated pork led to the custom of cooking pork to the well-done stage in this country. A minimum internal temperature of 185°F is often recommended. However, since it has been assumed that a gray color denotes well done pork, a pink color is usually suspect as denoting undercooked pork no matter what internal temperature was reached. In effect, degree of cooking was ruled out as an acceptance criteria with pork cooked in the home. Requirements of the Meat Inspection Division, USDA, (1960) for the destruction of *T. spiralis* by heat provide for a minimum internal temperature of 137°F. This means that many processed pork products, such as ham and sausage other than fresh pork sausage, are cooked to considerably less than 185°F. However, very little work has been reported on the effect of different cooking conditions on the organoleptic properties of pork.

Several investigators have studied the influence of fat marbling on pork tenderness and other acceptance criteria. Murphy and Carlin (1961) reported that marbling had a highly significant positive effect (1% level) on both tenderness and juiciness. Saffle and Bratzler (1959) found that taste-panel scores (acceptance) correlated with specific gravity, which, in turn, was a measure of fat content. Batcher and Dawson (1960) reported that tenderness in pork is related to fat marbling. However, in a later study Batcher *et al.* (1962) found that the effect of cooking on muscle tenderness is apparently influenced by many factors, and marbling score alone is not a reliable indicator.

It is generally believed that fresh pork is fairly uniform in tenderness, lacking the wide variations in tenderness found in beef. However, Batcher *et al.* (1962) found that there was a large variability in tenderness of raw and cooked pork muscles from different carcasses. Furthermore, they reported that the correlation between raw and cooked tenderness values as measured by the Kramer shear press was low and not significant. This was also found by Murphy and Carlin (1961), and is similar to results for beef found earlier in this series of investigations (Tuomy *et al.*, 1963).

Some attempts have been made to relate cooking conditions to the quality of the cooked pork. Weir *et al.* (1962), in working with braised pork chops, found that increasing the final temperature and time of cooking resulted in lower juiciness scores but did not significantly influence odor, flavor, or tenderness. The internal temperatures and times used in that study were 185°F; 200°F; 200°F plus 7 minutes; and 200°F plus 14 minutes. Webb *et al.* (1961) reported in a study designed to determine the effect of temperature and time of cooking on the palatability of pork loin roasts that tenderness scores were: a) reduced as the internal temperature was increased, and b) slightly increased as time was prolonged. That study used 14 pork carcasses with the loins cut into roasts of about 2.5 lb and four internal temperature treatments of 85°C (185°F), 73.9°C (165°F), 65.6°C (150°F), and 65.6°C maintained for 1 hr. Come-up times ranged from 152.5 ± 2 min for the 85°C internal to 102.0 ± 10.8 min for the 65.6°C internal. These times are similar to those reported in the literature on beef.

Weir (1960), in working with pork roasts, found that apparently identical pork roasts could have widely varying heating rates under the same controlled environmental conditions. No reasons were found for the different rates, but it was noted that the slower cooking roasts were more tender than the faster cooking, although flavor scores were not affected. Weir concluded that the heating rate

Table 1. Tenderness means on 9-point rating scale (average of 5 runs).

Temperature (°F)	Heating time (hr) 0	1	2	3	4	5	6	7
140	....	....	....	....	....	....	....	....
150	....	5.4	6.3	5.8	6.1	5.8	6.7	6.5
160	....	5.4	6.0	5.2	5.8	5.8	5.6	5.8
180		5.1	6.0	6.0	6.1	5.5	6.0	6.4
190		5.2	6.1	5.7	6.5	7.1	6.8	7.0
200		5.4	6.1	6.7	7.0	....	....	....
210		6.4	7.2	7.2	....	....	....	....

Table 2. Cuttability means on 9-point rating scale (average of 5 runs.)

Temperature (°F)	Heating time (hr) 0	1	2	3	4	5	6	7
140	6.5	6.4	6.6	6.8	6.6	6.9	7.0	6.3
150	5.2	5.4	6.0	5.6	6.2	5.6	6.4	6.5
160	5.8	5.3	5.8	5.3	5.8	5.8	5.6	5.8
180	5.3	4.4	5.9	5.9	6.1	5.8	6.6	6.8
190	5.0	5.4	6.4	5.8	6.5	7.3	7.4	7.5
200	5.2	5.5	6.4	7.3	7.6	....	....	....
210	4.4	6.3	7.6	7.9	....	....	....	....

Table 3. Shear-press means (average of 5 runs).[a]

Temperature (°F)	Heating time (hr) 0	1	2	3	4	5	6	7
140	251	235	229	253	221	252	208	289
150	373	351	305	334	255	326	266	262
160	289	409	327	409	319	342	309	310
180	419	461	291	323	388	358	364	323
190	439	287	297	307	294	212	243	226
200	390	317	267	268	194	215	226	207
210	374	242	176	158	......	......	......	......

[a] (Average sheer press value for raw meat, 120 lb.)

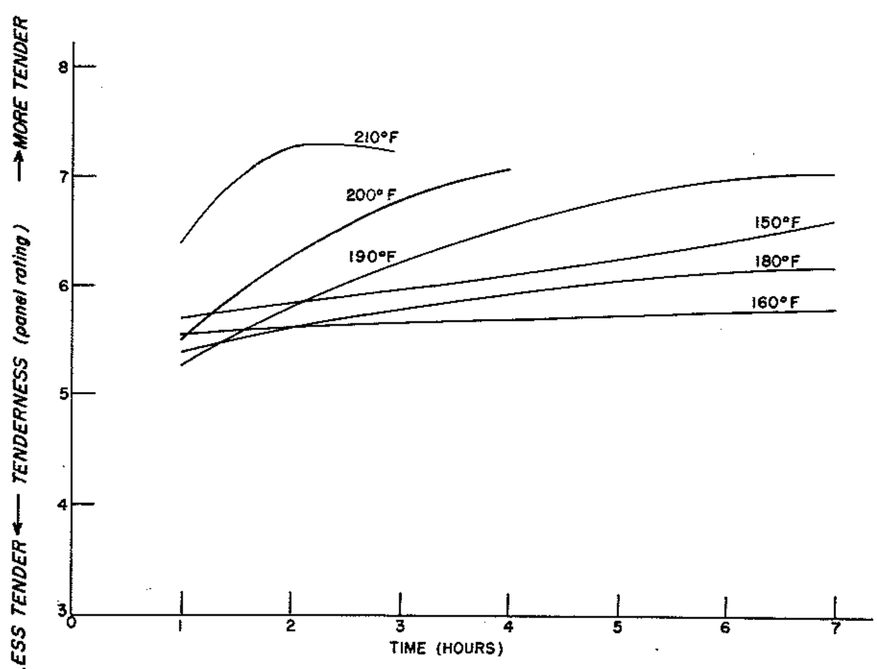

Fig. 1. The effect of temperature and time on the sensory tenderness of pork. The lines for each temperature were derived by the method of least squares from the results of five replications. Tenderness evaluations were made on a 9-point rating scale by a 10-member technological panel.

of the meat contributes significantly to the quality of cooked pork, and implied that time as well as temperature should be considered as affecting meat tenderness.

Cover (1943) pointed out that the two structures in meat which contribute to its toughness are muscle fiber and connective tissue. However, Winegarden *et al.* (1952) state that connective tissue is softened quite rapidly under the influence of heat above 65°C (149°F). This would indicate that with cooked pork as normally prepared, toughening of the muscle fibers by protein coagulation would be the major factor contributing to toughness.

Although not directly related to tenderness, browning of cooked pork is a quality factor which must be considered in process design for Armed Service rations. According to Pearson *et al.* (1962), the amount of brown color development in heated pork is related to the level of reducing sugars in the tissues. Since the reducing sugars will vary from carcass to carcass and even from muscle to muscle, the amount of browning in a given Armed Forces procurement could vary widely. Observations incidental to other studies at this Institute have indicated that process conditions probably will have to be held within certain limits regardless of tenderness considerations in order to prevent browning of cooked freeze-dried pork.

Since the effect of temperature is confounded with the effect of time when masses of meat are cooked, the two effects can be studied best when the cross section of the meat is small enough to permit rapid temperature changes throughout the piece. Thus, for this study, the meat was placed in cylinders with small enough diameter for rapid temperature changes yet large enough to be sliced for organoleptic evaluation.

EXPERIMENTAL METHODS

Procedures used in this study were identical with those used in the beef study. U. S. No. 1 pork loins (18–20 lb average) were received in the fresh chilled state with no control of quality other than grade and condition. Immediately upon receipt, the longissimus dorsi muscle was removed, trimmed of fat and connective tissue, and frozen in a −20°F blast freezer. The following day the frozen meat was cut on a meat saw into "logs" 1¼ inches square and about 8 inches long. Four to five logs were produced from each muscle. The logs were mixed to ensure randomization, individually wrapped in waxed paper, and stored at 0°F until needed.

For use, the frozen meat logs were tempered at 75–80°F for about ½ hr and then carefully cut down to fit inside open-end stainless-steel tubes ⅞ inch in internal diameter and 8 inches long. Sufficient filled tubes for a given run were placed upright in a wire basket and transferred to a water bath held 20°F above the temperature to be investigated. For run temperatures of 200 and 210°F, the bath temperature was 210°F. As soon as the internal temperature of the meat reached the run temperature, the wire basket was transferred to a water bath containing circulating water held at the run temperature. Tubes were removed at time intervals and immediately placed in 32°F water. Come-up time varied from 3 to 8 min, depending on the run temperature. Come-down time to less than 100°F was 3 min or less. Zero time was considered as when the meat reached the run temperature. The cooking temperatures used were 140, 150, 160, 180, 190, 200, and 210°F.

Disks of the product ¼ inch thick were evaluated by a panel of 10 technologists and by a L.E.E.-Kramer shear press, Model SP21. The panel rated the product for tenderness, cuttability, and flavor on 9-point scales, where the higher the number the more tender, more cuttable, or more flavorful the product. To determine cuttability, the panel members used standard non-serrated table knives. Shear-press results were reported as pounds pressure measured at the peak of the shear value. The panel was not asked to taste or rate for tenderness at the 140°F level or for the initial samples from any of the temperature runs.

RESULTS AND DISCUSSION

The average results of five runs for tenderness, cuttability, and shear press are shown in Tables 1, 2, and 3. Curves fitted to these data by the method of least squares (Figs. 1, 2, 3) show that the initial effect of temperature was a toughening that increased as the temperature was increased. This is similar to the initial effect of temperature on beef, and indicates that protein denaturation is responsible. The shear-press value for the raw pork averaged 120 lb (122 lb was the average for raw beef). For meat brought to 140°F, the value was 251 lb and for meat brought to 190°F, the value was 439 lb (Table 3).

It had been found with beef that, although the initial toughening with heat was similar, below 180°F there

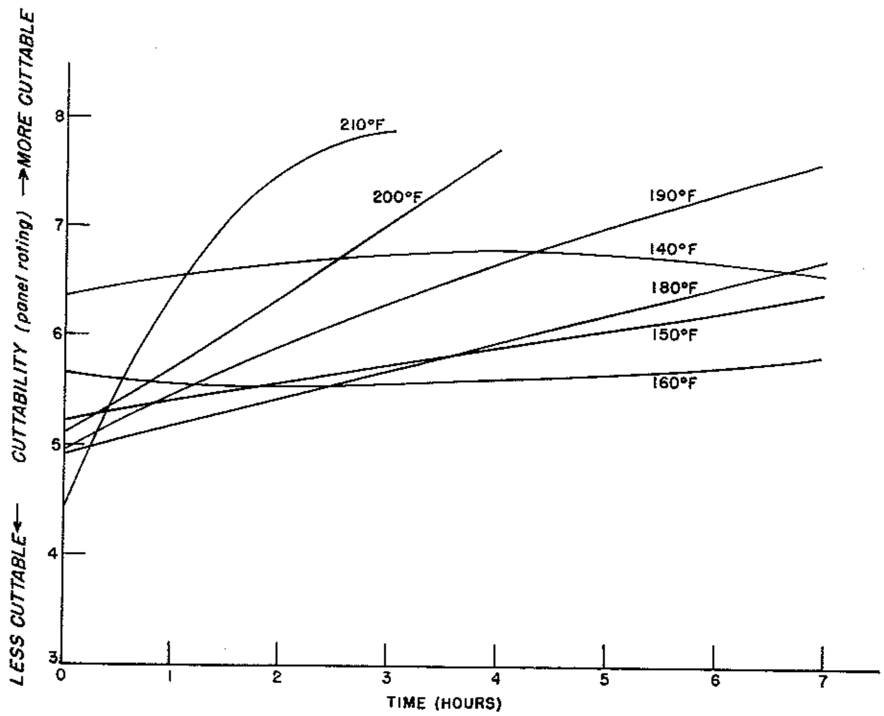

Fig. 2. The effect of temperature and time on the sensory cuttability of cooked pork. The lines for each temperature were derived by the method of least squares from the results of five replications. Cuttability evaluations were made on a 9-point rating scale by a 10-member technological panel.

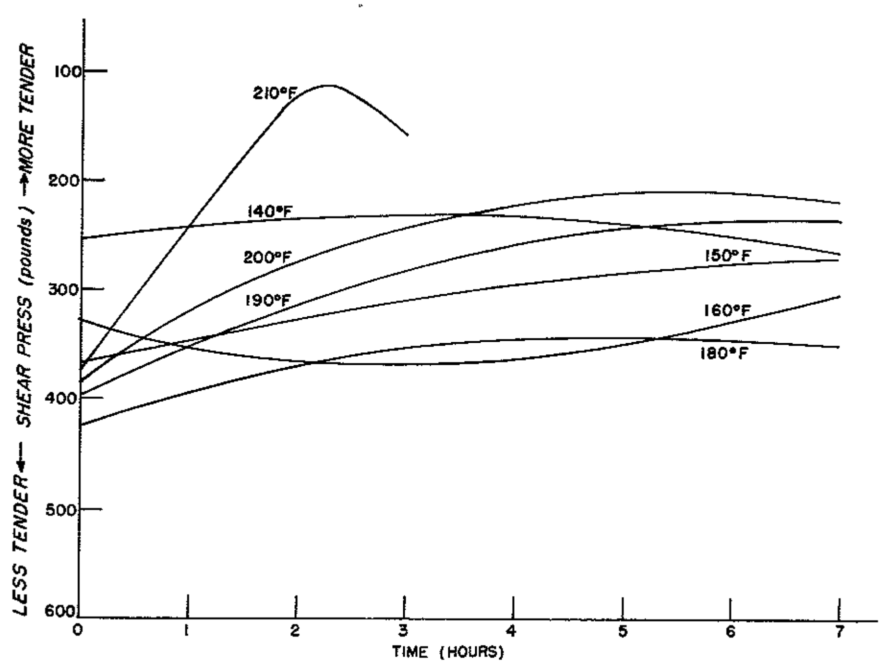

Fig. 3. The effect of temperature and time on the L.E.E.-Kramer sheer press values for cooked pork. The lines for each temperature were derived by the method of least squares from the results of five replications. Shear-press results are expressed as pounds pressure measured at the peak of the shear value.

Table 4. Flavor means on 9-point rating scale (average of 5 runs).

Temperature (°F)	Heating time (hr) 0	1	2	3	4	5	6	7
140	....	....	....	....	....	....	....	....
150	....	5.4	5.8	6.0	5.7	5.6	5.9	5.5
160	....	5.8	5.6	5.7	5.9	5.8	5.8	5.5
180	....	5.7	5.4	5.6	5.4	5.4	5.5	5.1
190	....	5.8	5.8	5.7	5.7	5.6	5.4	5.2
200	....	5.8	5.5	5.8	5.8	....	....	....
210	....	6.0	5.8	5.7	....	....	....	....

was very little tenderizing with time, whereas at 180°F and above the meat became tender at a rate and to a degree dependent upon both time and temperature. With pork this "break" at 180°F was not evident. At 140°F there was little change in tenderness with time. At 150°F and above there was an appreciable tenderizing with time. Outside of this, the changes in tenderness with time showed a pattern similar to that found with beef. However, pork never became as tough as beef, and the total range of tenderness was less. For example, from Fig. 2 it can be seen that the toughest pork encountered under any condition received a cuttability rating of 4.45, and the most tender a rating of 7.9. Equivalent ratings for beef over the same temperatures and time scales were 3.9 and 8.5.

After 4 hr of cooking at 210°F the pork fell apart so badly that it could not be sliced sufficiently well for evaluation. At 200°F the meat fell apart so badly after 5 hr that panel evaluations would have been questionable. However, shear-press evaluations were made. The falling apart was due not to disintegration of the fibers but to disintegration of the material holding the fibers together. In this respect, pork differed from beef in that beef did not fall apart until cooked 8 hr at 210°F. At this point the beef was mushy and the fibers disintegrated. In general the beef became slightly more tender than the pork with high-temperature cooking without falling apart.

There was considerable scatter of data due to variations between individual samples of pork. This scatter ranged up to 2.3 scale points in the panel evaluation for tenderness and cuttability, and 300 lb for the shear press. This bears out findings of Batcher *et al.* (1962) that there is a large variability in the tenderness of cooked muscles from different pork carcasses, in contradiction to general belief.

The average results of the technological panel evaluations for flavor are shown in Table 4. Very little change is shown with either time or temperature. However, panel comments indicated that at the end of 3 hr at 210°F the meat was beginning to take on a burnt taste. In addition, when the meat was cut it turned brown after a few minutes' exposure to air. At times longer than 3 hr both the burnt flavor and the browning were much more evident. At 200°F the brown color started to become evident at 5 hr and became more severe with time. However, it was not as severe, nor was the burnt taste as evident, as at 210°F.

The correlation coefficients for tenderness, cuttability, and shear press are shown in Table 5. The correlation for cuttability and shear press is not significant at 140°F. This is due to the small change in cuttability at this temperature. Therefore, the determinations by the panel and shear press were made upon the same degree of tenderness, and scatter around this point is due to random errors inherent in the methods rather than to assignable causes. The over-all correlations are good and show that the panel and shear press were measuring much the same thing.

Table 5. Correlation coefficients (r).

Temperature (°F)	Tenderness and shear press r	p	Cuttability and shear press r	p
140	......	......	—.560	[a]
150	—.848	.01	—.968	.001
160	—.780	.05	—.857	.01
180	—.719	.05	—.739	.05
190	—.805	.02	—.861	.01
200	—.878	.05	—.906	.02
210	—.970	.05	—.998	.001
Overall	—.835	.001	—.916	.001

[a] Not significant.

Informal observations in connection with other studies on cooked, sliced, freeze-dried pork at this Institute have indicated that browning with accompanying off flavors is more of a problem with pork than with freeze-dried beef. Comments by panel members in this study and the appearance of browning at the higher temperatures indicate that this factor should be taken into account in any cooking studies for cooked, freeze-dried pork. It is evident that the interim measure for obtaining satisfactory tenderness with freeze-dried beef for Operational Rations of more severe cooking cycles is not feasible with pork.

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The Armed Forces Food and Container Institute, Chicago, is now merged with U. S. Army Natick Laboratories, Natick, Massachusetts.